NOAA/NMFS Cooperative Monkfish Research Program
Completion Report

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Abstract

Multiple gillnet mesh sizes were used to establish robust retention probabilities of monkfish *Lophius americanus* in a collaborative effort using a commercial fishing vessel with fishermen collecting most of the data. An increase in mesh size of “tie-down” gillnets from 10 inches to 12 inches resulted in an increase in average length overall and an increase in average weight per trip of monkfish 8 lb or greater. Depth appeared to be a significant but minor factor in retention probabilities. Catch of non-target species was limited to 26% of the overall catch, and 13 taxa. Major non-target species catches were also significantly different in different mesh sizes, and in different depths. No protected, endangered, or threatened species were caught in 50 trips. Anticipated revenue from 10 and 12 inch gillnets was similar, despite an 80% decrease in monkfish less than 8 lb, due to premium pricing, increase in catch of large skates, reduced handling time, and reduced gear damage. Decreased catches of smaller monkfish implies lower mortality and increased stock size and reproductive potential.

Introduction

A fishery for monkfish (goosefish, American angler) *Lophius americanus* along the East Coast of the United States developed rapidly beginning in the mid-1980’s (Haring and Maguire 2008). Monkfish landings in the region exceeded 14,000 MT in 2006, valued at over US$37 million (Fisheries Statistics Division, National Marine Fisheries Service (NMFS), unpubl. data) surpassing all other finfish in value (Richards et al. 2008).

The fishery is managed under a two-stock structure. In the Southern Fishery Management Area, consisting of southern Georges Bank and the Mid-Atlantic Bight, gillnetting has grown to account for approximately 65% of the total catch (Haring and Maguire 2008, Richards et al. 2008). A minimum gillnet mesh size of 10-inch mesh was established primarily to reduce catch of species other than monkfish because little or nothing is formally known about the relationship between fish size and mesh sizes above six inches in monkfish gillnets (NEFMC and MFMC 1998). Indeed, little or no information on gillnet selectivity for this species or the closely related European species *Lophius piscatorius* is available in scientific literature. Some recent unpublished work has been conducted in the Faroe Islands (K. Zachariassen, Faroese Fisheries Laboratory, pers. comm.) that includes length frequencies of monkfish caught at several mesh sizes.

The New England Fishery (NEFMC) and Mid-Atlantic Fishery Management (MFMC) Councils, beginning in 2007, created a pool of fishing days to be used to support cooperative research to enhance management of monkfish. Research priorities included methods to reduce monkfish bycatch and discards, and establishment of a relationship between mesh size and minimum fish size. The goal of this project was to see if an increase in mesh size of gillnets from 10 inches to 12 or 14 inches resulted in an increase in average length overall and average weight of total catch by 1) using a range of mesh sizes to generate mesh size relationships for monkfish in gillnets, 2) determining if larger mesh sizes result in greater revenue by comparing catch numbers and weights, and average lengths, in different mesh sizes and 3) to compare bycatch of non-target species in larger mesh sizes.

Larger mesh sizes were theorized to maximize economic benefit to fishermen because over the last two years, larger monkfish have yielded a proportionally higher price per pound. In the winter of 2006, monkfish under 8 lbs round weight were $1.00/lb at market while large monkfish (over 8 lbs round weight) were sold at $1.65/lb. These distinct differences in price seem to be the future trend of the whole monkfish market to Asia. We theorized that this difference is large enough so that the increased average size of monkfish caught in 12-inch and larger gillnets, while resulting in fewer numbers of fish than in 10-inch gillnets, may result in greater profits to the vessel. The use of 12-inch mesh is industry practice for many monkfish fishermen – we sought to confirm the wisdom of the larger mesh size. Further, larger mesh may result in reduction of the take of smaller fish therefore allowing for another year or more of reproduction and subsequently higher fish population. Further, we hypothesized that the larger mesh sizes would result in lower bycatch of non-target species, reducing unnecessary impact. The study was additionally conducted over varying depths to exploit concentrations of monkfish as part of commercial practice but also to see if depth affected selectivity or bycatch.

Methods

Setting and hauling of gillnets was conducted on the F/V *Jessica Marie*, a fiberglass 45 ft (14 m) long, 800 hp (597 kW) combination lobster/gillnet vessel, on fishing grounds south of Rhode Island, USA to the edge of the continental shelf. Forty-two gillnets were newly constructed for the experiment and designed for highest monkfish catching efficiency. Nets were nominally 300 ft (91.4 m) long and were initially arranged into two strings of 21 nets each. Within each string were 7 panels each with 10, 12, and 14 inch (254, 305, and 356 mm) mesh openings. Mesh sizes were initially alternated sequentially in seven groups of three; later in the experiment, the last net was removed on each haul and reattached to the opposite end of the string to reduce any skewing of results due to string end effects.

Nets had unequal numbers of vertical meshes to maintain a constant height (145-150 in (368-381 cm) and constant effort. Ten inch mesh nets were 14.5 meshes deep; 12 inch mesh nets were 12.5 meshes deep; 14 inch mesh nets were 10.5 meshes deep. Mesh size was made easily identifiable in the field by a length of colored twine spliced into each individual net at each end. Gillnet heights were restricted by “tie-downs” (twine looped from the floatline to the leadline and back); resulting in a nominal height of 48 in (122 cm). The nets were fitted with 85 lb (39 kg) lead line, 3/8 inch (10 mm) diameter polypropylene float line, and floats at every 8 ft (2.4 m) interval. Nominal measurements were verified at the end of the experiment. Gillnet floatlines included breakaway links for whale conservation efforts and Airmar pingers (Milford, NH) were installed in compliance with harbor porpoise take reduction strategies. Two StowAway Tidbit Temperature Loggers (Onset Computers, Inc, Onset, MA) were attached to record bottom temperature at the beginning and end of the string.

Strings were set approximately east to west following industry convention to avoid gear conflicts. Both strings were set in approximately the same area. Gear was marked with a

16-ft (4.9 m) highflyer and a poly ball at each end, connected to a 0.5-in (13 mm) dia. buoyline, comprised of 2/3 sinking line and 1/3 floating line. The floating line section was attached to a 22 lb (12 kg) Danforth anchor at each end of the string, with 30 fm (55 m) of line from the anchor to the string. Sets followed the seasonal migration of monkfish, from 21-104 fm (38-190 m), and were post-stratified by depth. Sampling did not occur from July 1 to October 31 due to warm water and scarcity of fish.

Data were primarily collected by vessel captain and crew, following onshore training by DMF personnel. On three trips, a DMF biologist accompanied the vessel and verified appropriate sampling techniques. At the start of each haul, operational data including date and time, location in latitude and longitude at both ends of each string, water surface temperature, ocean bottom temperature and length of days fishing (soak) were recorded. As a string was hauled, monkfish and other catch from the different mesh nets were separated by into three different color-coded holding tubs (their color matched the color of the twine spliced in as an identifier) filled with seawater. At the end of the haul of each string, each monkfish was measured for weight to the nearest pound and total length to the nearest centimeter.

Non-monkfish organisms were identified and weighed. On early trips, non-target species were sometimes counted and not weighed. Three hauls were excluded from analysis because some smaller monkfish were discarded without measurement.

Data Analysis

Field data were entered into a customized relational database and analyzed with the open-source statistical program R, and with proprietary selectivity software (GillNet, Constat, www.constat.dk).

Target and Non-Target Catch Analysis

Monkfish catches were analyzed by weight and count collectively, and separated into two categories, <8 lb and 8+ lb, based on premium ex-vessel pricing for larger monkfish. Other species were selected for analysis based on substantial catch weights (Table 1). For species other than monkfish, only weights were examined, as numbers of individuals were not collected as part of the experimental protocol. Some non-target weights were estimated from count data. Exploratory analysis included examination of boxplots, trip-by-trip trends, and paired catches for each mesh. Based on these results, differences in catches between meshes were explored using plots of trip means with errors bars (± 1 SE), paired t-tests, and, finally, with randomization testing.

Randomization testing (Rago, 2004; Pol, 2006, Chosid et al. 2008) was conducted using catches from individual trips. For each species, any trip with non-zero catches in any one mesh size were included in the comparisons. Catches were paired and compared separately for the 10 and 12 inch mesh, and for the 12 and 14 inch mesh, with 1000 iterations. For each analysis, catch rates of each pair were randomly assigned, without replacement, to one of the two mesh sizes, and mean differences were calculated. We compared the observed difference in paired treatments against a distribution of the randomly assigned paired values. The reported probability value is the proportion of the randomly determined differences that are more extreme than the observed value without regard to the sign (Sprent, 1989), and therefore constitutes a two-tailed test.

Linear modeling was used to test for depth effects on catches of monkfish. Results from temperature probes were trimmed to include only bottom time; mean temperature on bottom is reported.

Size Selectivity

The theoretical basis for the indirect estimation of gillnet selectivity, or retention probability, using multiple mesh sizes was described by Hamley (1975) and further developed by Millar and Holst (1997). Our estimation of retention probabilities employs a log-linear model and follows methodology used by Madsen et al. (1999), Moth-Poulsen (2003), Fonseca et al. (2005) and Revill et al. (2007). Selectivity curves for this experiment are defined to be “contact-selection” curves, the probability that a particular-sized fish is captured, once it contacts the gillnet.

Maximum likelihood was used to fit selection curves with the SELECT method (Millar and Holst 1997), which uses the proportion of the total catch taken by each mesh size. The method was implemented using proprietary software (GillNet, Constat). Four unimodal Gaussian (normal scale, normal location, lognormal, and gamma) (parameterized in Millar and Holst 1997) and one bimodal curve (a mixture of two normal curves; parameterized in Revill et al. 2007) were fit to individual gillnet hauls, and to the lengths pooled over all catches. The curve that converged and that resulted in the lowest model deviance was defined as the best-fit.

Residual maximum likelihood (REML) was used next to estimate a mean selection curve from the curves fit to individual hauls, incorporating between-haul variation. The REML method was implemented with software (ECWEB, www.constat.dk) based on work by Fryer (1991) that allows fitting of the same five types of curves to the combined individual curves. The resulting mean curve that best fit the data was again selected by the lowest deviance. It was then visually compared to the curve fit to the pooled data.

Finally, trips were post-stratified into depth intervals to determine if selectivities changed with depth. Modal lengths and spreads were determined using the best fit (lowest deviance) model resulting from the initial REML analysis, and compared.

Other Analysis

Pairs of head circumference and total length measurements were compared for two sampling trips to indicate if similar populations of monkfish were sampled. The largest girth anterior of the pectoral fins was measured using hand pressure and a cloth tape on one trip and a girth measuring apparatus, also using hand pressure, on the other. Linear modeling was conducted on the resulting pairs to determine if the relationship differed between the two trips. A similar analysis was conducted on length and weight of monkfish.

Economic Analysis

The total counts at each length were used as an estimate of the underlying population. Total catch at length from valid trips was converted to catch per length per trip by dividing by the number of valid trips. Also, the length-weight regression from this study was used to define an estimated weight per fish for each length category. Retention probabilities for each mesh size were then applied to produce estimated weights per length per trip. For lengths of <61 cm. differential pricing of $1.00 per lb was applied; for larger fish, $1.65 was applied. The resulting estimated landed values per trip for each mesh size were then compared.

Results

Ninety-seven gillnet strings were set and hauled over 50 trips between 2 May 2007 and 3 April 2008 7 to 90 nm south of Martha's Vineyard, USA (Figures 1, 2). Apparent gear conflict led to loss of gear and changes in configuration. Between 9 and 12 February 2008, four nets of each mesh size (twelve nets) were lost from one string. The intact string and the shortened string were reset on 12 February, and hauled on 17 February. After hauling, the intact string and the shortened string were combined into one 30 net string. This string was hauled on 21 February, reset and hauled again on 26 February 2008. Following consultation among the PIs, the 30 net string was divided into two 15 net strings. Equal amounts of each mesh size were retained in all strings, resulting in equal effort. Valid gillnet hauls (N=94) and trips (N=49) were post-stratified based on locations.

Unequal numbers of valid trips were conducted within each depth stratum, as a result of following monkfish concentrations. Further, due to the loss of nets, the number of nets per trip were not equal throughout the experiment. Nearly equal numbers of trips were completed between 20-30 fm (N=14), 30-50 fm (N=14), and 70-90 fm (N=15). Fewer trips were completed between 50-70 fm (N=4)and 90-105 fm (N=2). Soak durations averaged 3.8 days (range: 2-6 days). Due to mishandling of temperature loggers during the latter part of the experiment, bottom temperatures were not collected for all sets (Figure 2). Of those collected, bottom temperatures ranged from 5.6-12.8 °C (avg: 9.5 °C). Surface temperatures ranged from 7.4-18.3 °C (avg: 10.6 °C) (Figure 2).

An estimated total of 133,203 lb (60,547 kg) of organisms were caught; over 99,000 lb (45,000 kg; 10,500 individuals) were monkfish, approximately 74% of the total catch (Table 1). Only three individual monkfish were under the minimum landing size (43.2 cm; 17 in TL). Thirteen other taxa of macrofauna were also captured. Five species caught in quantity were further analyzed: winter *Raja ocellata*, barndoor *R. laevis*, and little *R. erinacea* skates; spiny dogfish *Squalus acanthias*; and summer flounder (fluke, *Paralichthys dentatus*). Less than 70 lb were caught of Atlantic mackerel *Scomber scombrus*, bluefish *Pomatomus saltatrix*, golden tilefish *Lopholatilus chamaeleonticeps*, Atlantic cod *Gadus morhua*, scup *Stenotomus chrysops*, silver hake (whiting, *Merluccius bilinearis*), horseshoe crab *Limulus polyphemus*, and unspecified hake (*Urophycis, Merluccius, Physicis* sp). Mackerel, cod, scup, and whiting were caught by the 10-in mesh nets. No further analysis was conducted on minor species.

Three 10-in mesh nets and 2 each of the 12 and 14-in nets were measured at the conclusion of the experiment under an adaptive strategy – if nets had shown substantial within-net variation, more nets would have been measured. Post-experimental measurements of the remaining gillnets indicated fidelity to specifications, and substantial similarity in gear characteristics and surface area within and between mesh sizes. Due to the similarity of the gillnets, and the equal within trip effort, catches were not adjusted for effort.

Monkfish

Randomization testing, paired t-tests, and graphical analysis demonstrated that monkfish catch counts and weights were reduced significantly between 10 and 12-in mesh, and between 12 and 14-in mesh ($p<0.01$, $N=49$, Figure 3). Analysis of separate weight categories also showed significant differences between mesh sizes. Far fewer small monkfish (<8 lb) were caught in the 12-in mesh than in the 10-in mesh nets ($p<0.01$, $N=49$); similarly, less weight of smaller monkfish was caught in 12-in mesh compared to 14-in mesh ($p<0.01$, $N=49$, Figure 3). Greater numbers of larger monkfish (8+ lb) were caught in the 12-in mesh than in either the 10-in ($p=0.04$, $N=49$) or the 14-in mesh ($p<0.01$, $N=49$)(Figure 3). When weights of larger monkfish are compared between nets, the same pattern was observed, but the significance level of the 10 and 12-in comparison increases ($p<0.01$, $N=49$)(Figure 3).

Other species

Pairwise comparisons by randomization testing of the catch weights (lb/trip) of little, barndoor, and winter skates, spiny dogfish, and summer flounder by mesh size were nearly universally significantly different, although with different trends (Figure 4). Little skate catches represented the only exception: no significant difference was observed between catches in 10 and 12 inch mesh ($p = 0.88$); between the 12 and 14-in meshes, a reduction was marginally significant ($p=0.10$). Little skate catches were the least common among the five species; they were caught on only six trips and therefore the results are least robust. Barndoor skate catches increased from 10-in to 12-in mesh nets ($p<0.01$, $N=43$), and were higher in the 14-in mesh than in the 12-in ($p=0.02$, $N=43$). For winter skate catches, the 12-in mesh nets had higher catch rates than the 10 ($p=0.04$, $N=45$) or 14-in mesh ($p=0.02$, $N=45$). Summer flounder ($N=45$) and spiny dogfish ($N=43$) showed highly significant reductions ($p<0.01$) from 10 to 12-in mesh, and from 12 to 14-in mesh. Paired t-tests confirmed these results; plots of means ± 1 SE also confirmed the results (Figure 4), except for winter skate, where overlap of standard errors suggested non-significance.

Depth Effects

ANOVA on a linear model of monkfish counts by depth appeared to be significant (($p<0.01$) for both factors). Examination of boxplots (Figure 5) of monkfish counts by depth interval and mesh indicated that catch counts per trip varied amongst depths without a clear trend. However, the analysis is complicated by unequal effort between depth intervals. The highest levels of catch (>100 fish per mesh per trip) were in the 20-30 and 30-40 fm intervals; catches were observed through all depth intervals. These patterns were consistent for small and large monkfish when examined separately.

Depth effects on catch of other species were observed. Skate catches were highly depth specific: little skate were caught only between 20 and 40 fm; barndoor skates were nearly absent from sets in the 20-30 and 80-110 fm ranges, and concentrated in the intervals in between (Figure 6). Winter skates were caught across all depths, but principally in shallower areas, including very large catches (>1000 lb per trip) in the 30-40 fm range (Figure 6). Summer flounder were caught primarily in the 30-80 fm range (Figure 7); spiny dogfish were absent from the 80-110 fm range, but present in approximately equal amounts throughout the other depth ranges (Figure 7).

Selectivity Analysis

Boxplots of lengths of all monkfish pooled by size indicated that median monkfish length increased significantly ($P<0.05$) with increasing mesh sizes. Observed median lengths of monkfish were 59 cm (23.2 in) TL (IQR:55-64, n=5663) in the 10–in mesh, 67 cm (26.3 in) TL (IQR: 62-72 cm, n = 3125) in the 12-in mesh, and 72 cm (28.3 in) TL (IQR: 66-78, n= 1199) in the 14-in mesh (Figure 8).

Catch-at-length was first combined for each trip. Modeling on a trip-by-trip basis was possible for all unimodal curves; examination of the results of the SELECT and REML modeling indicated that the lognormal distribution consistently provided the best fit. While the resulting lognormal models for some trips were overdispersed (GOF/df > 1.2), every trip was able to be incorporated into the model. For some individual trips, the normal scale or normal location models provided better fits, but the lognormal appeared to provide the best fit overall. For a subset of other trips, and for the REML analysis, the bimodal distribution appeared best. However, many trips did not converge under the bimodal curves, and others resulted in unusual curves and were discarded. The lognormal therefore was selected for further analysis because it included more data.

Lognormal curves were fit to data from all trips, and displayed some expected variability but overall appeared to converge to similar curves (Figure 9). As a next step, REML curves were generated where possible for each depth; too few trips were conducted in the deepest stratum (80-110 fm) for REML analysis - these data were pooled for comparisons. Comparisons of curves indicated that selectivity curves by depth did not differ much. For example, the modal length in the ten inch mesh ranged from 61-63 cm across depth strata (Tables 2, 3). Nevertheless, mean selectivity curves by depth stratum and overall were developed using REML results (Figure 9).

Head Circumference-Length Relationships

Head circumference and total length pairs, 208 in all, were collected on two trips (29 June and 18 December 2007). The relationship between head circumference (cm) and length (cm) was not different between trips (ANOVA, $p > 0.77$), indicating that similar populations were sampled. A linear relationship using pooled data of head circumference = 2.37 (±2.29 SE) + 0.8 (±0.03 SE)*total length, and a reciprocal relationship of total length = 16.18 (±2.17 SE) + 0.91 (±0.04 SE) *head circumference, were developed (R^2 = 0.72) and appeared to be good fit, based on residual analysis. Reciprocal graphical prediction limits were produced to aid conversions (Figure 11).

Length-Weight Relationships

Individual monkfish lengths (N=9987) and weights were natural log-transformed, and analyzed by ANOVA with length and depth as independent variables. Depth interval was not significant ($p=0.27$) as an explanatory variable. Data were pooled and fitted with a linear regression line, resulting in a relationship of ln(weight)= -9.67 (±0.05 SE) + 2.85 (±0.01 SE) *ln(total length). The reciprocal relationship was found to be ln(total length)= 3.5 (±0.003 SE) + 2.85 (±0.001 SE) *ln(weight) (R^2 = 0.85). Reciprocal graphical prediction limits are presented in Figure 12.

Economic Analyis
Estimates of predicted catch indicated that ten-inch gillnets yielded an estimated 492 lb of monkfish less than 8 lbs and 834 lb of fish 8 lb and greater. Under differential pricing, the average predicted trip yield would be $1869. For 12-in gillnets, the estimated weights are 167 lb of smaller monkfish and 1100 lb of larger monkfish for an estimated revenue of $1983. Fourteen inch gillnets yielded approx. $1140 per trip (27 lb of smaller monkfish; 675 lb of larger monkfish).

Discussion
Some unusually-shaped fish do not show size-selectivity in gillnets. Paddlefish *Polyodon spathula* (Scholten and Bettoli 2008) captured in tied-down gillnets showed no relationship between fish size and mesh size in selectivity experiments. Baranov (1914, cited in Hamley 1975) felt that of the three primary ways fish are caught in gillnets (wedging, gilling, and tangling), only the first two could depend on mesh size. The monkfish's unusual morphology and bottom-affinitive habits, coupled with our observations of its entanglement in gillnets, suggested that monkfish also might not show size-selectivity. However, our results establish that monkfish exhibit size selectivity in tied-down gillnets, with fish lengths increasing with mesh size.

The large sample size from this study, and the clear trends, indicate that this information can be used in monkfish stock assessment, and adds valuable fishery information on a data-poor stock. While data were only collected from the Southern Fishery Management Area, the results of the gillnet selectivities from this study are similar to preliminary results from a similar project conducted in the Northern Fishery Management Area (S. Eayrs, Gulf of Maine Research Institute, unpubl. data). In that study, lognormal curves also provided the best fit to the data, and the modal sizes and spreads were similar (10-in: mode = 61.1 cm; spread = 8.1; 12-in: mode = 73.3 cm; spread = 9.7; 14-in: mode = 85.5 cm; spread = 9.4) (Table 3).

The lognormal shape of the selectivity curves displays a slight skew to the right. This shape is typical in gillnet selectivity studies, and in some recent work, a bimodal distribution has provided the best fit. The bimodal distribution implies more than one capture process (gilling and tangling, for example) and this implication is appropriate for species such as Atlantic cod *Gadus morhua* with prominent mouth structures. Monkfish appear to be less varied in the ways in which they are caught in gillnets; our observations suggest that tangling along the spines is the primary method. The skewed distribution has no clear interpretation, but the unusual flexibility and geometry of the monkfish contribute to the skewness.

The use of 12-inch mesh gillnets, larger than the 10-in legal minimum mesh size, may result in economic benefits, although the revenues from the two mesh sizes are similar.

Use of twelve inch gillnets would also translate into reduced deck time handling small monkfish and undesired non-target catches such as spiny dogfish, summer flounder, and little skate that potentially damage gillnets. The 12-inch mesh also would benefit from an average 200% increase in poundage of barndoor skate, and 30% more winter skate, based on observed catch. While the analytical methodology did not capture variability in the length-weight relationship, the results still appear to support industry use of 12 inch mesh.

The minimum mesh size for gillnets and otter trawl codends targeting monkfish in this fishery is 10-in. Only 3 of over 5,900 monkfish caught in 10-in gillnets in this experiment were under the minimum landing size (43.2 cm; 17 in TL). Our selectivity modeling predicts extremely low catches of undersized fish in 10-in gillnets, and none using 12 or 14-in gillnets.

We conclude that fourteen inch mesh nets are currently not economical. However, we caution that the results from this study are based on the underlying populations of fish available to the gear during its conduct. Changes in those underlying populations, both in density and in average size, would likely result in changes in catch composition. And, larger mesh sizes, while typically capable of reducing catches of small fish, can result in increased capture of undesired non-target species.

Nevertheless, the monkfish population and fishermen both currently can benefit from the use of larger meshes, as we presume that survival of smaller monkfish is improved by reduction of discards of smaller fish, and near elimination of sublegal fish. While monkfish discard mortality is uncertain and no data exists for individual fisheries, discard survival in limited studies ranged from 8 to 57 percent (NEFMC and MFMC, 1998). Decreased mortality of small monkfish implies increased stock size and reproductive potential for the monkfish stock. Our results support conclusions by Thangstad et al. (2006) in Norwegian waters, who suggested a change towards only using large-meshed gillnets could increase the long-term yield of the fishery by 20-25%.

Catches of non-target species were limited, and suggest that the fishery has lower non-target impact than monkfish trawl fisheries. Our informal observations suggest that many individuals captured and discarded were still alive upon discarding, especially larger individual summer flounder. Trawl capture is likely to produce higher rates of discard mortality in monkfish and non-target species, and lower size-selectivity.

Non-target species catches appeared to show depth effects that are consistent with published epth ranges for these species (Collette and Klein-MacPhee (2002)) These relationships provide preliminary evidence for the possibility of time-area management of non-targets, if necessary. However, our data were limited in the deeper depths, and should be used with caution. The length-weight relationship presented probably bears closer analysis, although its value is limited by the rounding of weights to the nearest pound. This rounding was a result of the practicality of data collection at sea by crew. Nevertheless the results are similar to those reported by Armstrong et al. (1992).

Non-target catch did not include any protected or endangered species, including turtles and marine mammals (nets were configured to meet requirements of take reduction plans). Indeed, no rare or threatened species were captured, and most non-target species taken in abundance are common. These results are a notable improvement over those reported by ASMFC (2007). That report cited tie-down monkfish gillnets as a primary source of mortality for Atlantic sturgeon *Acipenser oxyrhynchus* and that most sturgeon encounters occurred in waters shallower than 50 m (27 fm). Approximately 16% of our effort occurred in areas shallower than 27 fm, and no encounters with sturgeons occurred. Comparison of observed sets, mortalities and discards with ASMFC (2007) suggests that the particular area of this study has not produced many sturgeon encounters. These results imply that spatial or temporal factors, or fishing gear construction or practice, may provide avenues for sturgeon avoidance.

This project represents a unique (to us) and successful partnership between fishermen and scientists: Bowen was the grantee of the research set aside, administered funding, purchased equipment, and satisfied reporting requirements, and collected the vast majority of the data at sea with his crew. Through these activities, he took on administrative and data collection responsibilities usually assumed by biologists. The contributions of Pol and Szymanski were limited to advising, training, data quality control, and analysis and writeup. This partnership encouraged collection of more data at less expense, resulting in more robust results, to the benefit of the resource and resource users. In addition, valuable relationships of trust and respect were established among the participants.

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Table 1: Estimated total species weights (lb) by mesh size caught in monkfish gillnets.

		Mesh Size (in)			
Species	**Scientific Name**	**10**	**12**	**14**	**Total**
Monkfish (Angler, Goosefish)	*Lophius americanus*	46,841	35,512	17,034	99,387
	Count	5,903	3,311	1,286	10,500
Winter skate	*Raja ocellata*	6,069	7,871	5,656	19,596
Spiny dogfish	*Squalus acanthias*	2,247	1,390	503	4,140
Summer flounder (Fluke)	*Paralichthys dentatus*	2,082	1,059	356	3,497
Barndoor skate	*Raja laevis*	1,113	1,878	2,579	5,570
Little skate	*Raja erinacea*	361	344	94	799
Atlantic mackerel	*Scomber scombrus*	66			66
Bluefish	*Pomatomus saltatrix*	45	21	20	86
Golden tilefish	*Lopholatilus chamaeleonticeps*	13	30		43
Atlantic cod	*Gadus morhua*	4			4
Scup	*Stenotomus chrysops*	3			3
Silver hake (Whiting)	*Merluccius bilinearis*	1			1
Horseshoe crab	*Limulus polyphemus*		6		6
Hake, unspecified	*Urophycis, Merluccius, Physicis sp*			5	5

Table 2: REML parameter estimates and standard errors for each depth interval (fm) and for all trips combined using the log-normal selection curves

	Parameter			
	m		**s**	
Depth (fm)	**Est.**	**Std. Dev.**	**Est.**	**Std. Dev.**
20-30	4.167	0.001	0.158	0.001
30-40	4.137	0.002	0.154	0.001
50-60	4.159	0.006	0.163	0.003
60-80	4.159	0.002	0.155	0.008
90-110	4.141	0.002	0.151	0.001
All Trips	4.156	0.001	0.157	0.000

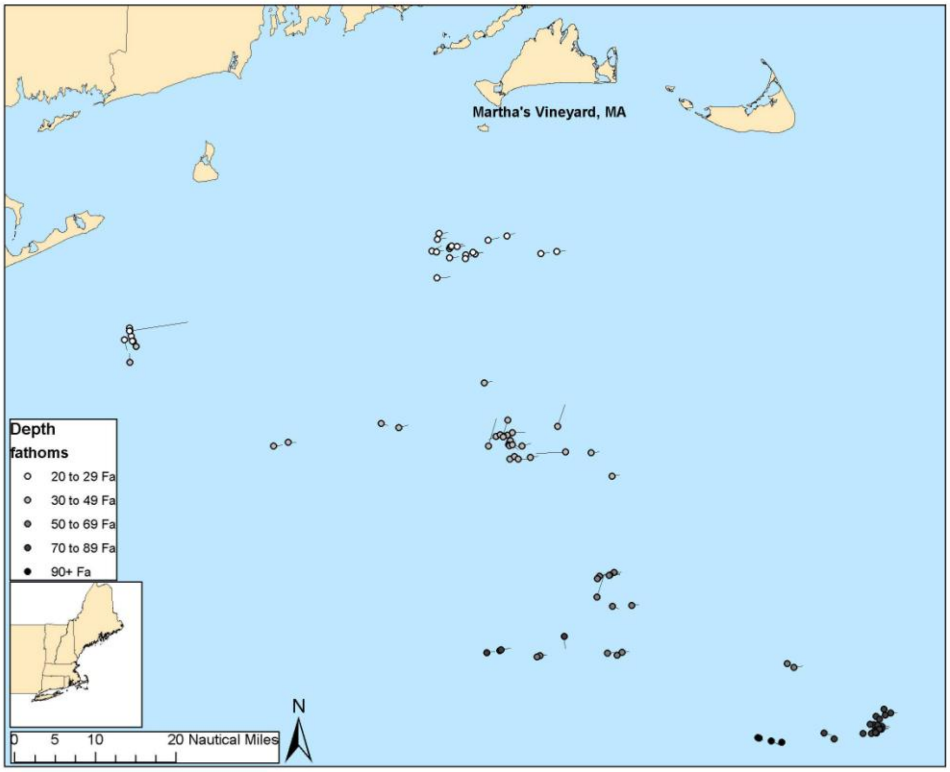
Table 3: Modal lengths and spreads for three mesh sizes at five depth strata, and overall, estimated from REML log normal scale fits.

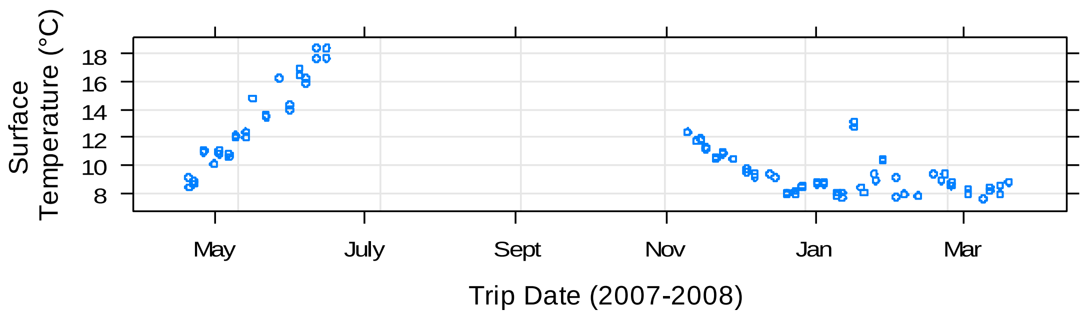
	Mesh size (in)					
	10		**12**		**14**	
Depth (fm)	**Mode (cm)**	**Spread (cm)**	**Mode (cm)**	**Spread (cm)**	**Mode (cm)**	**Spread (cm)**
20-30	63	10	76	12	88	12
30-40	61	10	73	12	86	11
50-60	62	11	75	13	87	12
60-80	62	10	75	12	87	12
90-110	61	10	74	12	86	13
All Trips	62	10	75	12	87	12

List of Figures

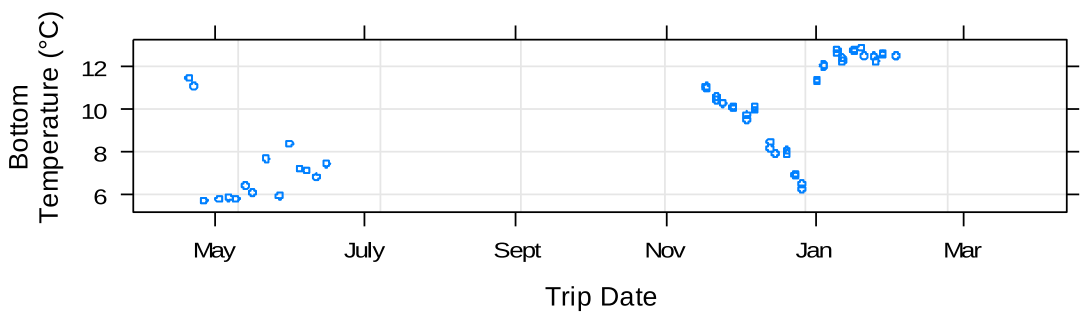
Figure 11: Reciprocal plots displaying monkfish head circumference and total length, and a linear regression line. Outer lighter lines depict 95% prediction limits. Histograms display marginal distributions of observed values for the parallel axis. White lines mark every five observations.

Figure 12: Reciprocal plots displaying natural log-converted monkfish lengths and weights, with a linear regression line. Outer lighter lines represent 95% prediction limits.

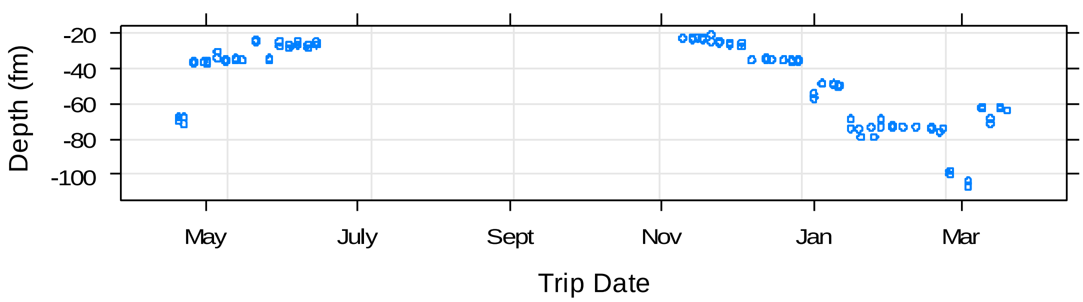

Martha's Vineyard, MA
Depth
fathoms
20 to 29 Fa
30 to 49 Fa
50 to 69 Fa
70 to 89 Fa
90+ Fa
0 5 10 20 Nautical Miles
N



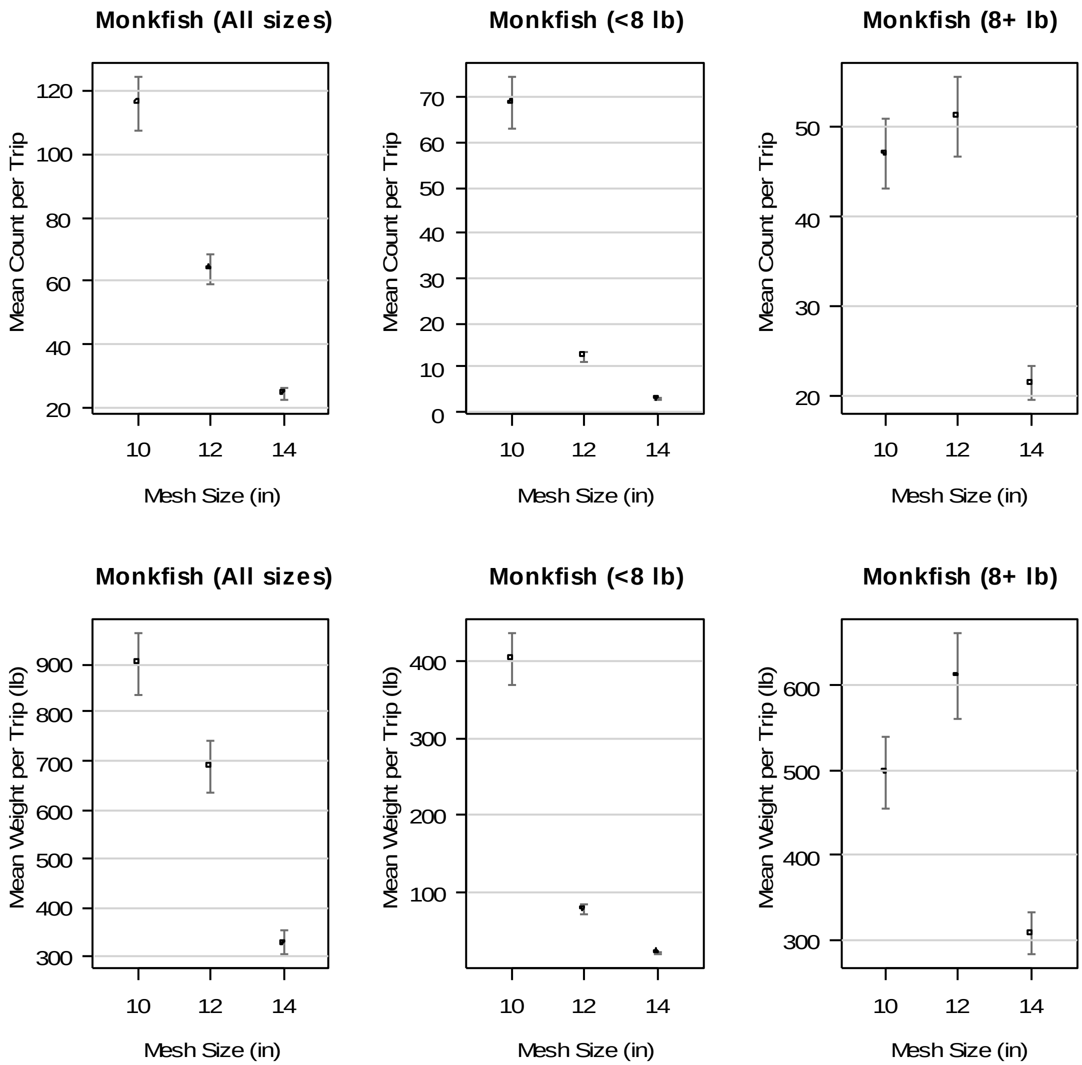
Surface
Temperature (°C)
18
16
14
12
10
8
May
July
Sept
Nov
Jan
Mar
Trip Date (2007-2008)

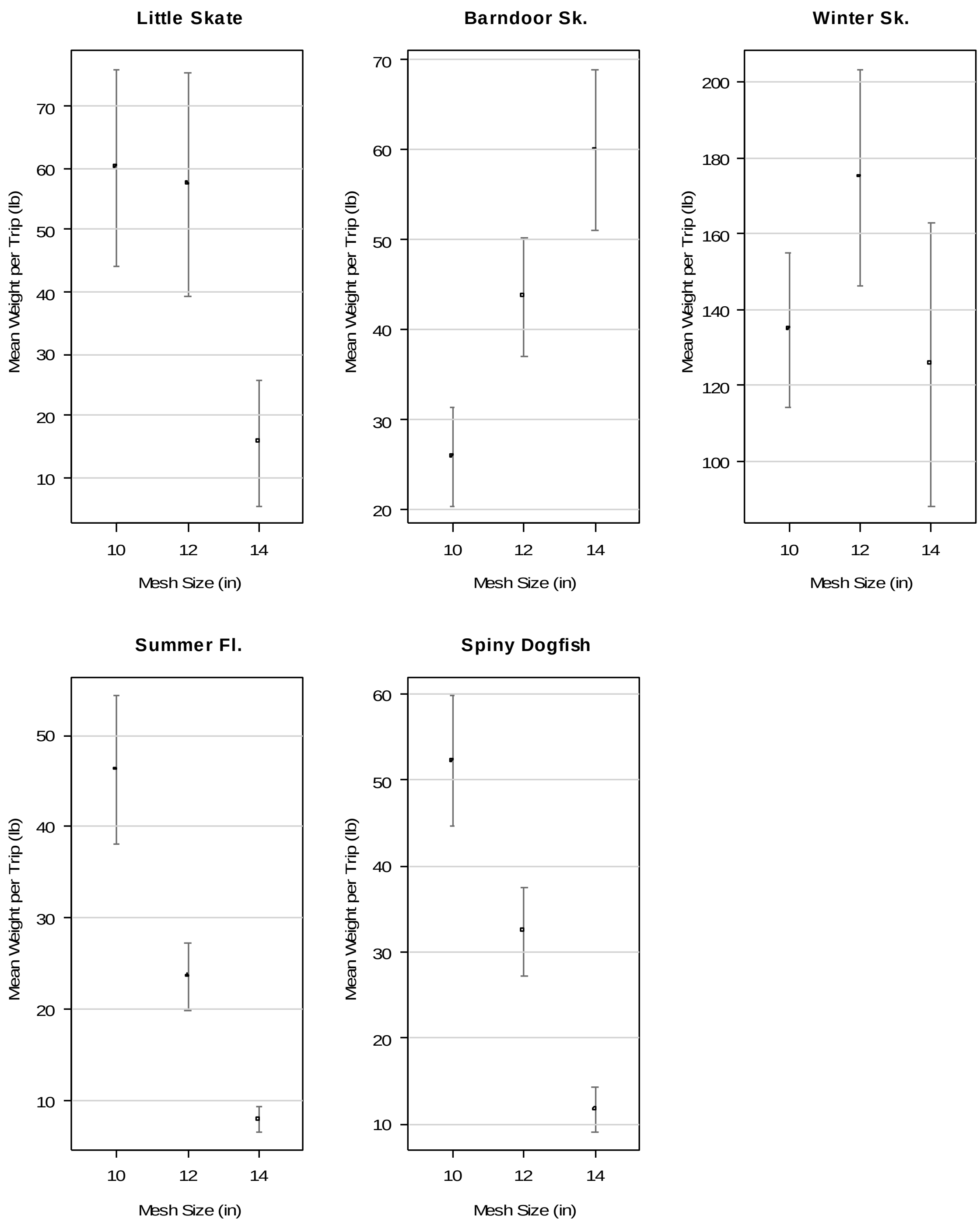


Bottom
Temperature (°C)
12
10
8
6
May
July
Sept
Nov
Jan
Mar
Trip Date

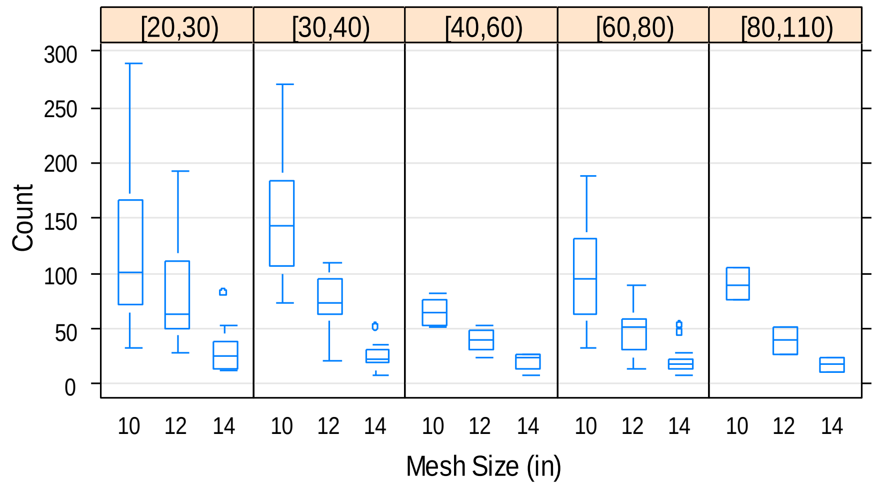


Depth (fm)
-20
-40
-60
-80
-100
May
July
Sept
Nov
Jan
Mar
Trip Date

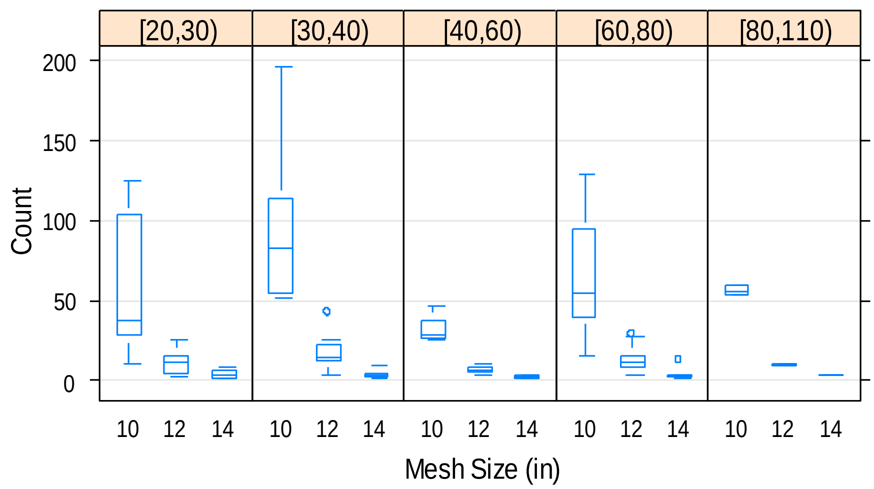

Monkfish (All sizes)
Mean Count per Trip
20
40
60
80
100
120
10
12
14
Mesh Size (in)
Monkfish (<8 lb)
Mean Count per Trip
0
10
20
30
40
50
60
70
10
12
14
Mesh Size (in)
Monkfish (8+ lb)
Mean Count per Trip
20
30
40
50
10
12
14
Mesh Size (in)
Monkfish (All sizes)
Mean Weight per Trip (lb)
300
400
500
600
700
800
900
10
12
14
Mesh Size (in)
Monkfish (<8 lb)
Mean Weight per Trip (lb)
100
200
300
400
10
12
14
Mesh Size (in)
Monkfish (8+ lb)
Mean Weight per Trip (lb)
300
400
500
600
10
12
14
Mesh Size (in)


Little Skate
Barndoor Sk.
Winter Sk.
Summer Fl.
Spiny Dogfish
Mean Weight per Trip (lb)
Mesh Size (in)
10
12
14
10
20
30
40
50
60
70
100
120
140
160
180
200

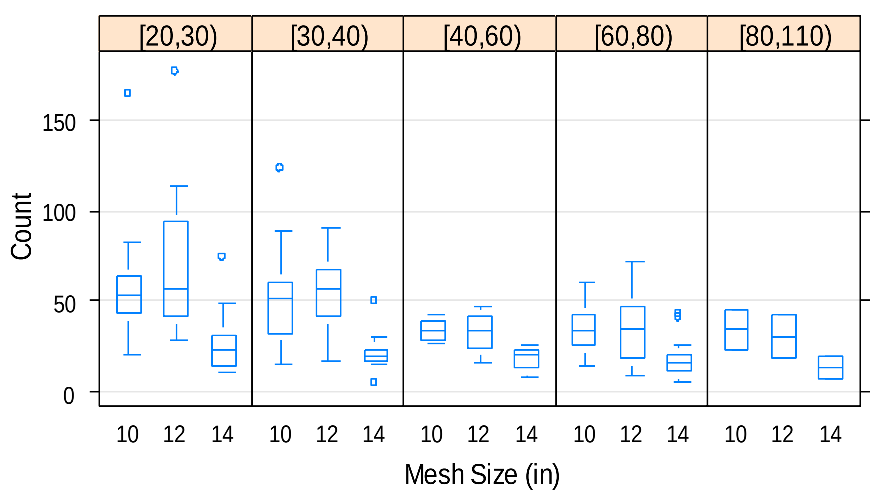
Monkfish (All sizes)



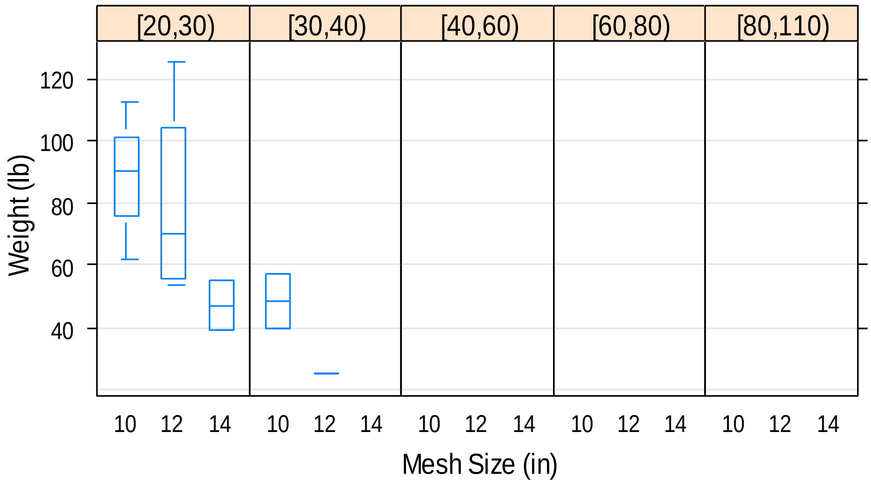
Monkfish (<8 lb)



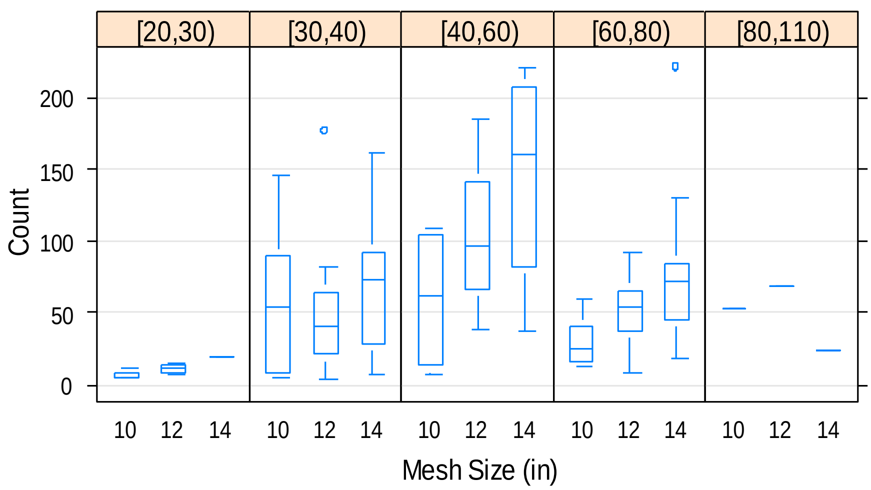
Monkfish (8+ lb)



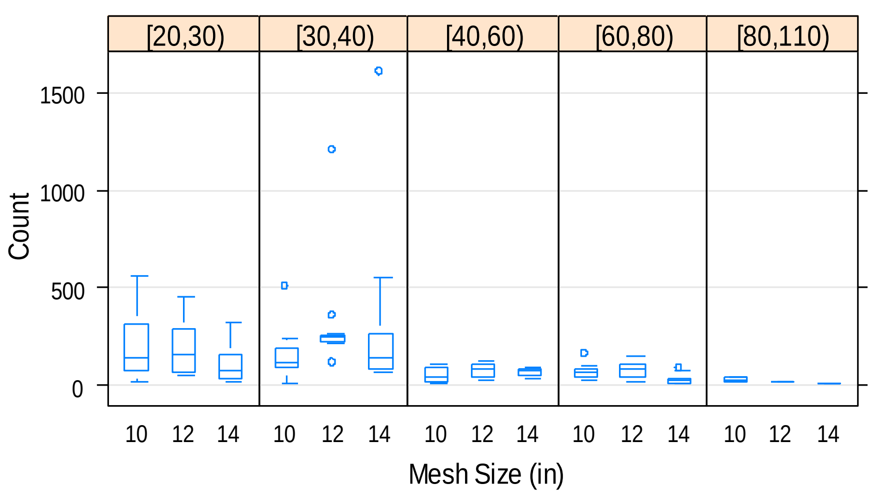
Little Skate



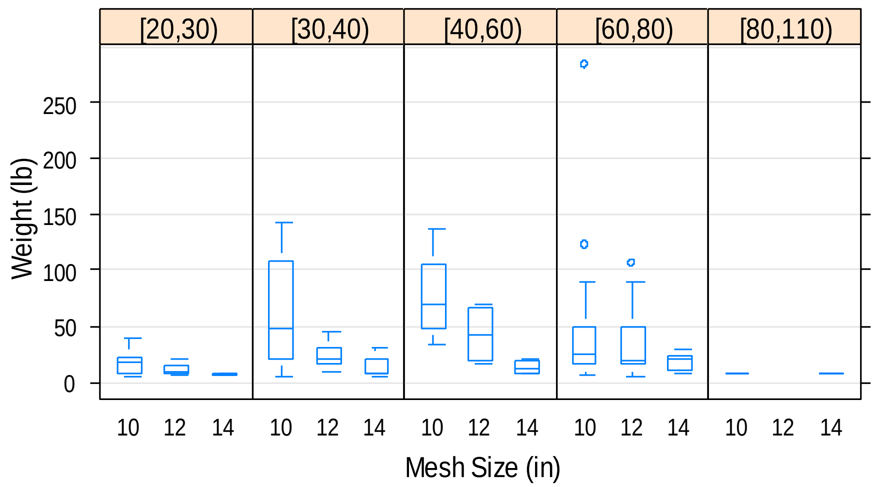
Barndoor Skate



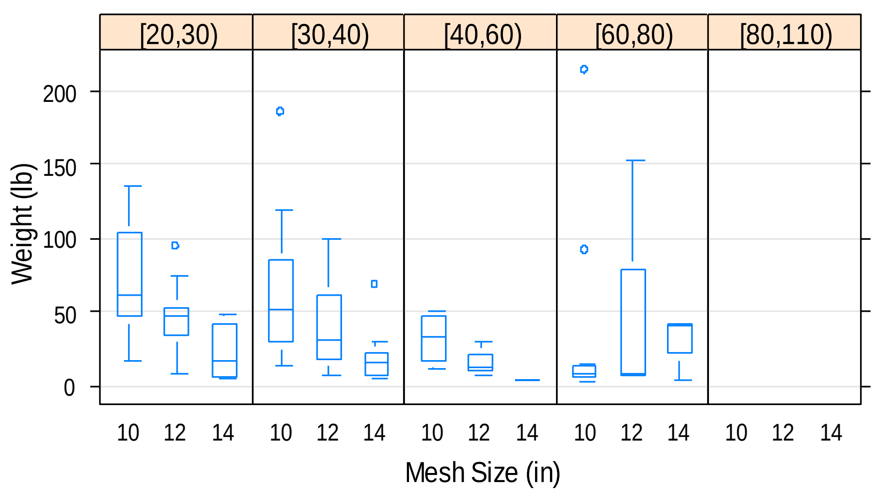
Winter Skate

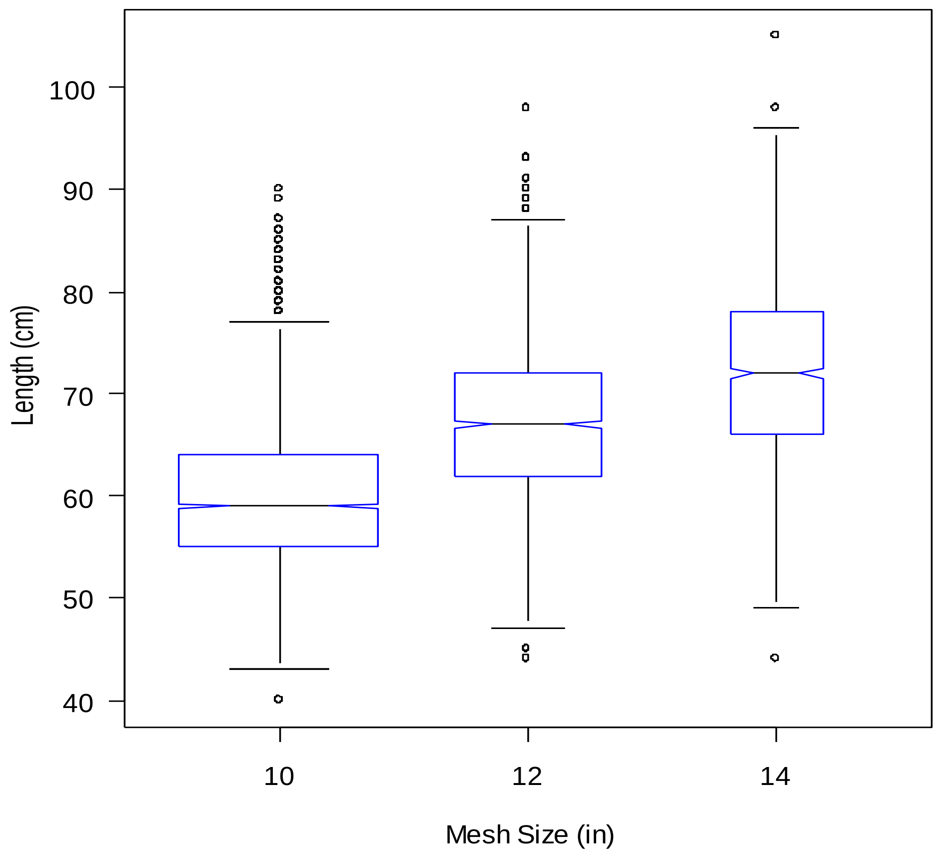


Summer Fl.

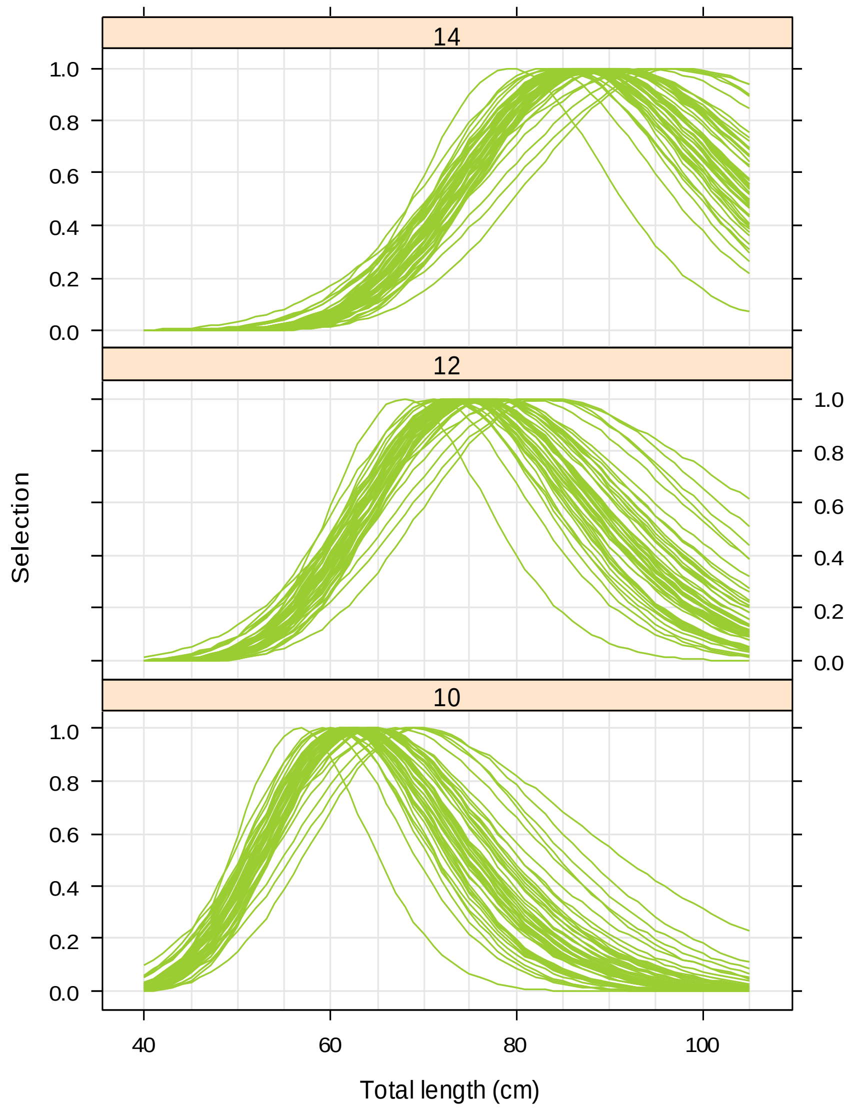


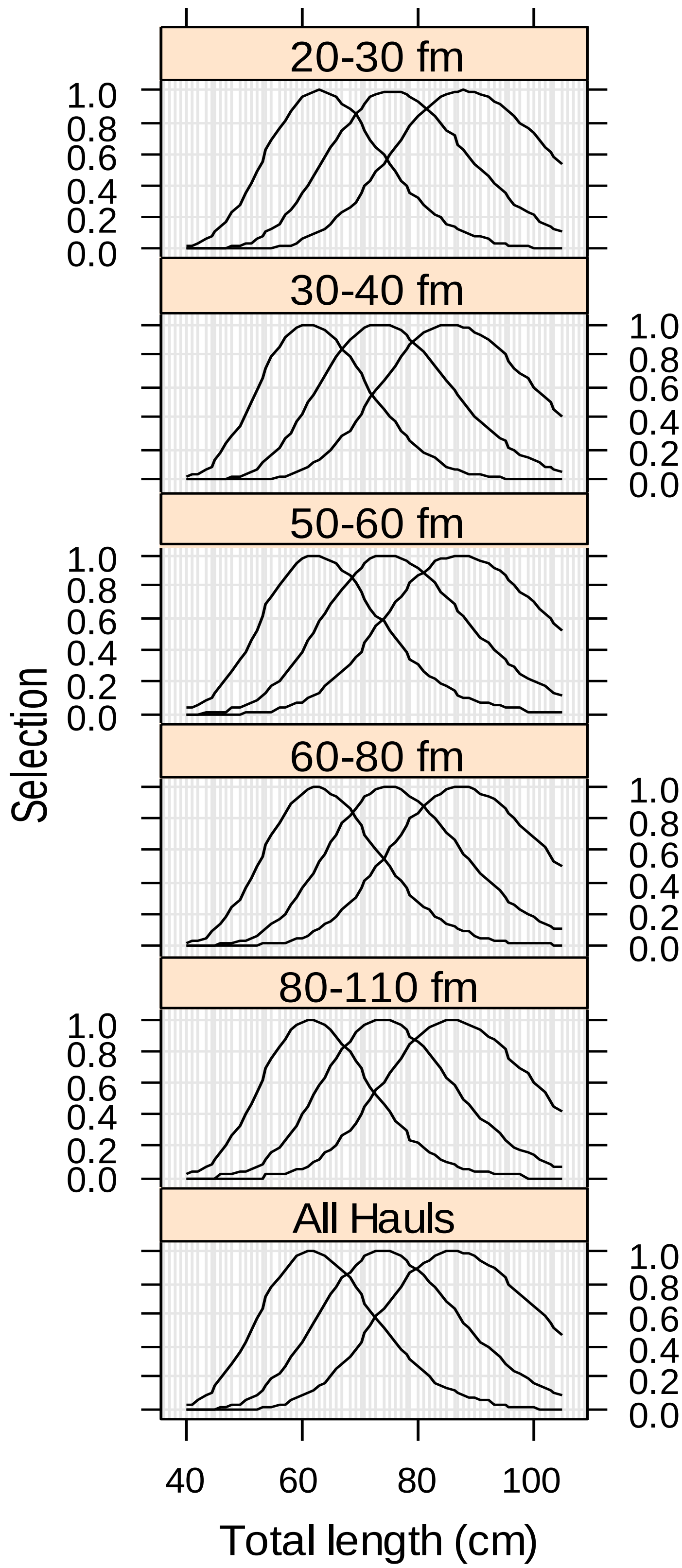
Spiny Dogfish

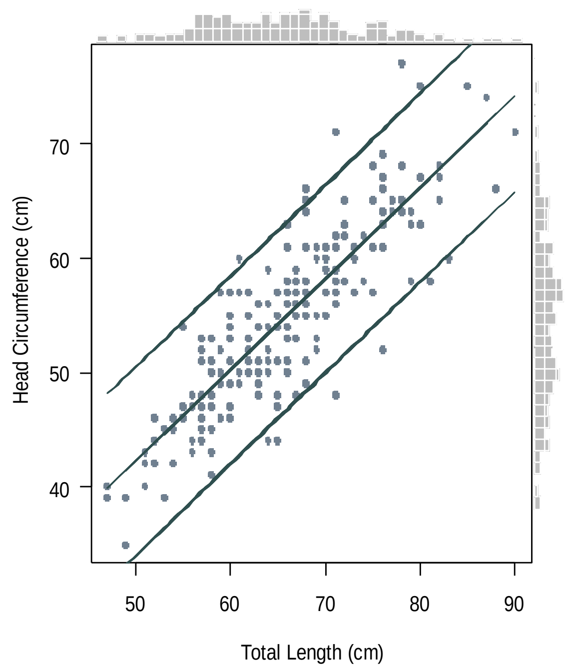


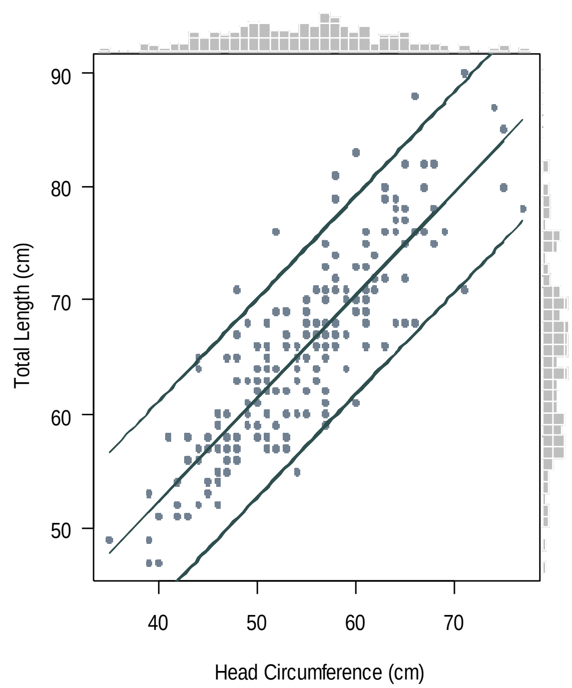


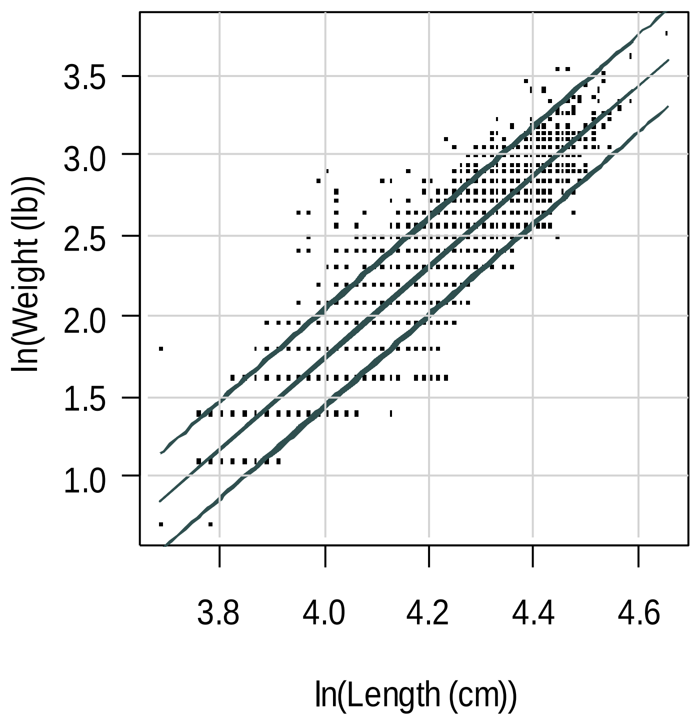
Length (cm)
100
90
80
70
60
50
40
10
12
14
Mesh Size (in)


14
12
10
Selection
1.0
0.8
0.6
0.4
0.2
0.0
40
60
80
100
Total length (cm)

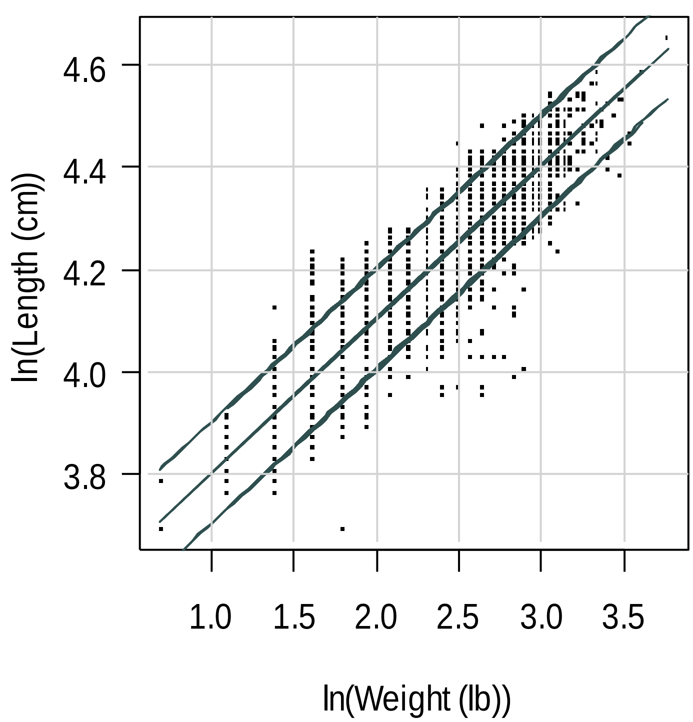

20-30 fm
30-40 fm
50-60 fm
60-80 fm
80-110 fm
All Hauls
Selection
1.0
0.8
0.6
0.4
0.2
0.0
40
60
80
100
Total length (cm)


Head Circumference (cm)
40
50
60
70
50
60
70
80
90
Total Length (cm)


Total Length (cm)
50
60
70
80
90
40
50
60
70
Head Circumference (cm)



ln(Weight (lb))
ln(Length (cm))
3.8
4.0
4.2
4.4
4.6
1.0
1.5
2.0
2.5
3.0
3.5



ln(Length (cm))
ln(Weight (lb))
1.0
1.5
2.0
2.5
3.0
3.5
3.8
4.0
4.2
4.4
4.6